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ABSTRACT

This paper outlines the rationale of the Fundamentals Underlying Number (F. U. N.) program, and describes Unit I, which is primarily intended for nursery and kindergarten children. This unit develops concepts for sets, numbers, and relations. Each major concept is broken into finely sequenced levels, and at each level instruction is through two basic games: "Find It" (the child identifies an example of the concept) and "Make It" (the child constructs an example of the concept). Procedures for playing these games, the special materials used, the concepts covered, and the spiraling of the sequence are all illustrated in this paper. (MM)

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THE RATIONALE AND DESCRIPTION OF THE F.U.N. (FUNDAMENTALS UNDERLYING NUMBER) PROGRAM

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In recent years, educational and psychological researchers have at one time or another focused much of their attention on young children and how they learn. There are differences of opinion among researchers as to how young children learn, to what extent they ought to learn, and to the kinds of learning they ought to acquire. However, most would agree that the early childhood years are among, if not the most important years of learning in a child's life.

During the past six years the authors have been involved in experimental and normative research on the development of mathematical learning in young children. Based on the findings of our research and on our experiences in working with young children we have created the F.U.N. (Fundamentals Underlying Number) program. The primary goal of F.U.N. is to develop with young children the fundamentals underlying number via sets, set relations and their properties, and set operations.

In essence, we believe mathematics is made up of systems of related ideas or concepts. It is a way of thinking. Through centuries of experience - and careful reflection about that experience - man noted patterns, saw contrasts, and recognized similarities and stabilities embedded in apparent dissimilarities. Like man's other creative works (art, music, literature), mathematics can give the learner a sense of competence, of self-esteem, of autonomy based on reason.

Evolving from the systems of ideas we call mathematics man gradually developed a variety of overt behaviors such as counting, measuring, and

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computing. Although these procedures prove useful in tackling many day-to-day problems, the essence of mathematics is not merely a set of observable behaviors to be trained into a child. It is not the rattling off of sounds like "one, two, three..." It is not the paper and pencil manipulation of symbols. Such behaviors useful as they are, are only the visable signs of the fundamentals underlying them - the system of ideas. Moreover, these overt procedures are only useful to those who have acquired the concepts underlying them.

The F.U.N. program attempts to reflect this philosophy of mathematics.

Rationale

The rationale from which F.U.N. evolved is based on a variation of the interactional view of cognitive development as articulated by Kohlberg (1968). It consists of four main phases: 1) Content-Structural Analysis, 2) Environment-Exemplar Analysis, 3) Behavioral Indicator Analysis, and 4) Instructional Analysis.

Phase I Content-Structural Analysis

In the Content-Structural Analysis phase a logical hierarchy for a given mathematics topic is developed. The hierarchy or content structure represents a set of mathematically precise definitions of the concepts and/or principles necessary for the logical development of the mathematics topic and the tentative sequence through which a learner would acquire the structure.

A content structure for a topic, depending upon the scope of the topic, will have several substructures. Also, a substructure for one topic may be a substructure of another. For example, the structure for the union of disjoint sets may be a substructure for both addition and multiplication of whole numbers.

The mathematics definitions stated in a structural analysis may be referred to as "mathematics content objectives". The precise statement of an

objective facilitates identifying those concepts and principles structurally related to that objective. For example, a mathematics content objective for the greater than relation on sets may be stated as follows: For two finite sets A and B, set A is greater than set B if and only if set B is equivalent to a proper subset of A. From this statement one can see that the learner must acquire the concepts or principles of set, proper subset, and equivalence. A complete structural analysis would contain statements for all these terms. It should be made clear, however, that such definitions as statements are not the desired learning products. Knowing the definition merely as a statement may be the poorest of outcomes--empty verbalism.

Phase II - Environment--Exemplar Analysis

In Phase II, Environment--Exemplar Analysis, the stages or levels of each concept specified in the content structure of Phase I is operationally defined and ordered along a continuum. The authors take the position that the acquisition of concepts is not an all or nothing affair. Hence, we sought a systematic way of operationally defining an hypothesized order of levels for a given concept.

If one takes as a working definition of a concept that of Gagne's--the capacity of a learner to give a common response to physically different stimuli--the ordering of a concept's levels might be operationalized in terms of the attributes of the stimuli employed in environmental exemplars. For example, a set of sounds (non-spatial) differs in physical objectivity from a set of wooden blocks (spatial). Yet each set could be an exemplar for a number concept. Concrete objects may differ in stimulus similarity from one another within and/or between sets in shape, size, color, substance, or arrangement. A set which includes only spatial elements differs from a set which includes spatial and non-spatial elements. Hence, sets of exemplars which are

similar in physical objectivity may represent a stage or level of a concept. It may be hypothesized that the difficulty of a level for a concept will increase as the degree of physical objectivity or similarity among the stimuli decreases.

Phase III - Behavioral Analysis

The task in Phase III, Behavioral Indicator Analysis, is to create or describe a set of overt behaviors which would indicate the attainment of each level of each concept defined in the content analysis of Phase I. Effort is greatly facilitated by the exemplar analysis of Phase II. In Phase II a vast variety of conditions are specified for each level of a concept in which a behavior might be exhibited. For example, if a child has acquired the mathematics content objective for the greater than relation cited above, then he should be able to identify and/or construct a set greater than a given set when exemplars differ in physical objectivity or stimulus similarity. The exhibiting of a variety of such behaviors by different learners would indicate the differing levels of their attainment of the objective.

Phase IV - Instructional Analysis

In Phase IV, Instructional Analysis, a set of activities and materials are designed to develop and facilitate the learners acquisition of each concept in the content structure of Phase I. The instructional analysis essentially ties together Phases II and III in an orderly fashion. The effectiveness of an activity and materials is based on the behavioral indicators described for each level of a concept. A unit of instruction would constitute the most efficient ordering of the concepts and principles included in a given content structure.

DESCRIPTION OF THE F.U.N. PROGRAM

As previously mentioned, the F.U.N. Program (which evolved from the preceding rationale) is designed to help children acquire the fundamentals underlying number. Structured activities and materials are used in attempting to guide a child from a state of perception to a state of conception with respect to number.

The most immediately noticeable feature of the Fundamentals Underlying Number Program is that the lessons are all "games". The teacher's plans and procedures are called "game plans". The games are fun for children, easy to play, non-competitive, and actively involve participants throughout. The game formats are designed to help sustain the child's curiosity and motivation, and encourage maximum independence through a self-confirmation process, whereby the child determines for himself whether his responses are correct or not - and why.

The basic organization of the F.U.N. Program is the carefully ordered sequence in which the games are played. This sequence has three major aspects: 1) the order in which the major concepts are presented; 2) the progression of levels within each concept; and 3) the spiraling of levels for given concepts in stages.

Ordering of Major Concepts

Unit I of F.U.N., which is completed, develops concepts for Sets, Numbers, and Relations. Three major concept areas were identified as the central objectives of this unit. The order in which these concept areas are developed is that which research indicates is most effective:

1. One-to-one correspondence
2. Greater than, less than (Greater than first)
3. Equivalence class and order

Several mathematics content objectives "cluster" around the major concept areas. The materials and procedures are designed to simultaneously develop these related concepts with the appropriate major concept area.

Unit 2 of F.U.N. which develops concepts for Sets, Numbers, and Operations is currently being designed.

Ordering of levels within concept

Each major mathematical concept introduced in F.U.N. is broken down into finely sequenced levels. At each level the concept is developed through two basic games: "Find It" (the child identifies an example of the concept) and "Make It" (the child constructs an example of the concept). As the child progresses from level to level of a concept, i.e. one-to-one correspondence, the basic game formats remain the same, but materials and questions appropriate to the next level are substituted.

The levels of a concept reflect increasing difficulty for the child. The games move gradually from concrete examples of the concept (such as a set of blocks) to symbolic (the counting set, the words "one, two, three,..." etc.). The number and degree of differences among examples of the concept increases. For example, at early levels, the child identifies equivalent concrete sets arranged in identical patterns. At higher levels he identifies equivalent sets arranged in varied patterns, or makes a set of sounds equivalent to a set of blocks (see Figure 1).

Spiraling concepts and levels in stages

The order in which concepts are acquired is a critical factor in concept learning. This does not mean, however, that a child must acquire all the levels of one concept before he can begin to learn the lower levels of a second. Hence, F.U.N. spirals concepts. Games in one Stage develop specified levels of each mathematics content objective, then the following Stage recycles through the next levels of these same objectives (See Figure 2).

GAME PLANS

For the first level of each concept introduced in F.U.N. the teacher will find a Detailed Game Plan for both the "Find It" and "Make It" games.

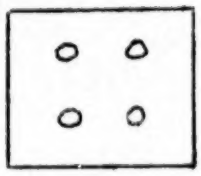
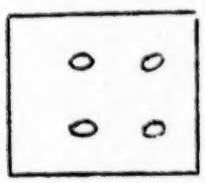
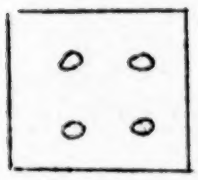
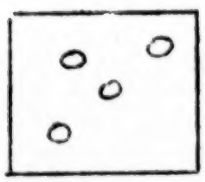
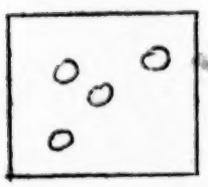
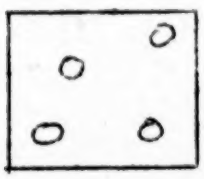
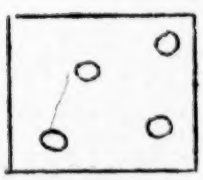
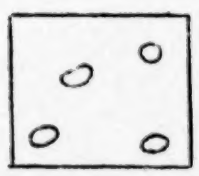
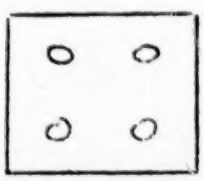
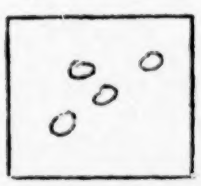
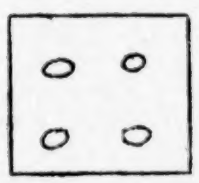
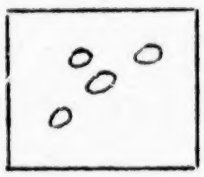
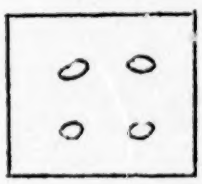
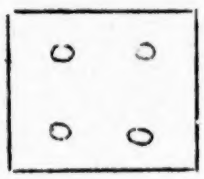
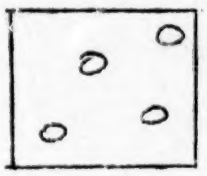
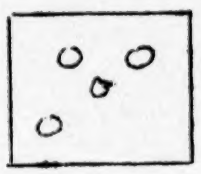
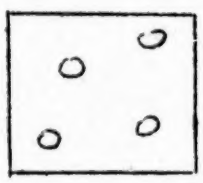
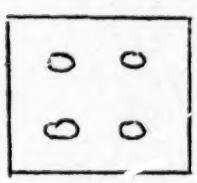
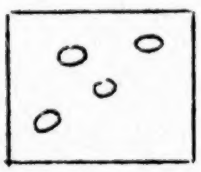
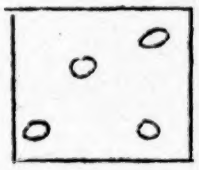
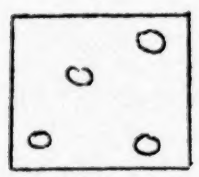
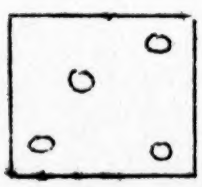
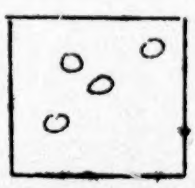
FIND IT			MAKE IT		
LEVELS OF DIFFICULTY	SAMPLE SET	IDENTIFIED SET	LEVELS OF DIFFICULTY	SAMPLE SET	CONSTRUCTED SET
1.			1.		Spatial
2.			2.		Spatial
3.			3.		Spatial
4.			4.		Non-Spatial
4b. 5.					
5a.			5.		Non-Spatial
5b.					
6a.			6.		Non-Spatial
6b.					

Figure 1. Levels of difficulty for Find It and Make It games of F.U.N. Unit I - Stage 1 (Pictoral Representation).

Stage 1: Concrete Sets, 0-6

All games in Stage 1 use concrete manipulative objects to develop concepts of one-to-one correspondence, greater than, less than, equivalence class and order. These concepts are developed using sets of 0-6 members.

Stage 2: Sets and Counting, 0-6

The games in Stage 2 recycle through the same objectives as Stage 1, extending each by introducing counting sets which are visual-concrete (Numeral caps), then visual-abstract (numeral cards and number word cards) and auditory-abstract (verbal-sounds). Concrete objects are still used and are available for self-confirmation, but less reliance on them encouraged. Objectives are developed with sets of 0-6 members.

Stage 3: Reading and Recording, 0-6

This stage recycles and extends the same objectives and introduces simple recording and reading about what the children have been doing. This is done through an "experience chart."

Stage 4: Sets, Counting, Reading, Recording 0-9

Stage 4 recycles all the levels of previous objectives but extends them to include sets of up to 9 members.

Figure 2. A General Description of the Stages in the F.U.N. Program, Unit I.

The plan includes a list of: 1) the mathematics content objectives of the game, 2) the general and specific expected behaviors which indicate achievement of the objectives sought, 3) the child's self-confirmation process, 4) the materials needed, 5) how the game is played, and 6) the questions and phases the teacher can use to guide the child's learning. Also indicated are some mathematically inappropriate phases that should be avoided whenever possible.

MATERIALS

All of the games in F.U.N. are played with the same basic set of materials in varying combinations.

Set Boards - 60 plastic boards, each containing a set of 0-9. Set boards have been specially designed so that set configurations appear as holes on one side, raised bosses (bumps) on the reverse. Sets are arranged in 3 types of patterns: Standard, Bilinear, and Scatter. See Figure 3.

Blocks - 108 3/4" hardwood blocks (9 each of 3 shapes and 4 colors). Blocks fit easily into holes on set boards; one block per hole.

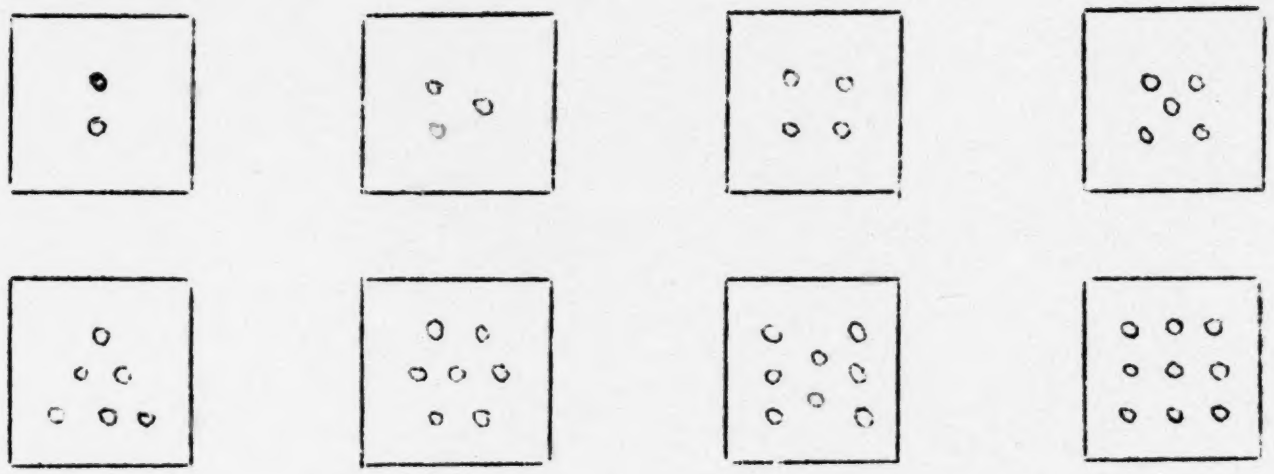
Plastic Cubes - 270 plastic cubes (27 each of 10 colors). Cubes fit snugly over raised bosses on set boards.

Numeral Caps - 54 plastic "caps" with black numerals (6 each of 1-9), fit snugly over plastic cubes and raised bosses of setboards.

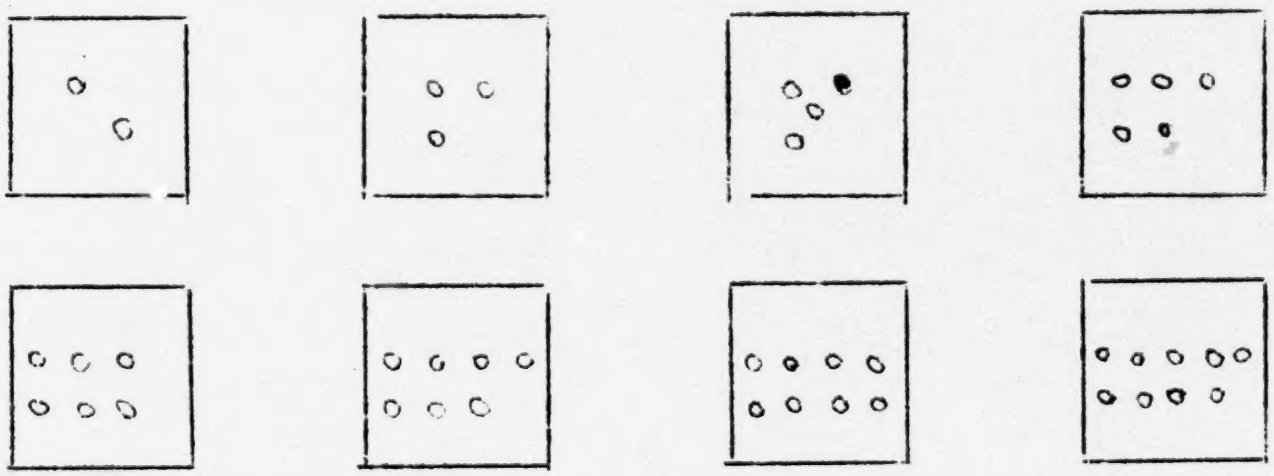
Spinner Cloth - large circular piece of flexible vinyl. Around the outside edge of the cloth are eight slots, into each of which a set board can be placed. A spinner is mounted on a suction cup at the center of the spinner cloth. See Figure 4.

Counting set boards - 6 plastic boards, each containing 9 rows of bumps/holes. Each row on the board has one more member than the previous row, beginning with one and ending with nine.

Standard



Bilinear



Scatter

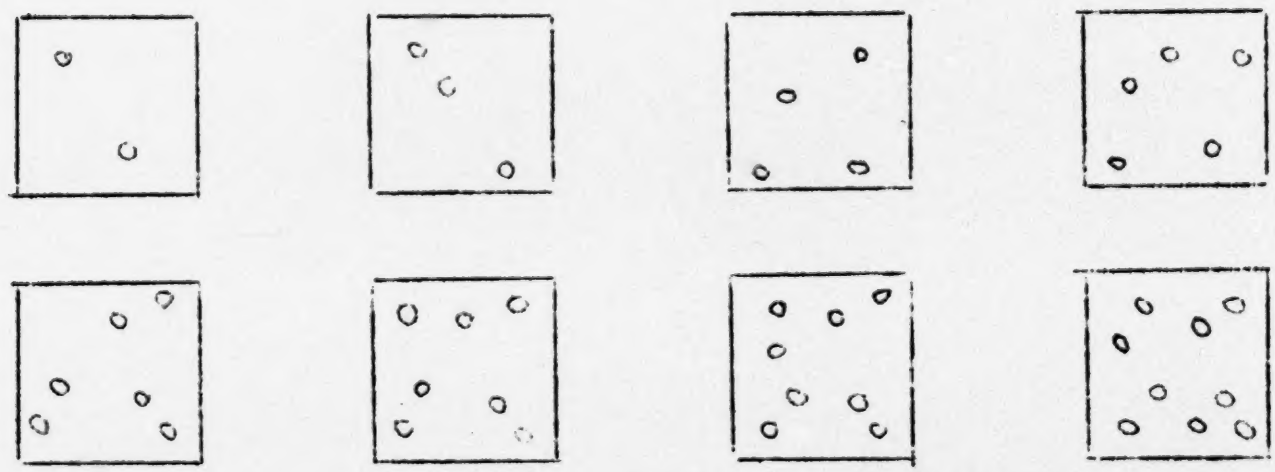


Figure 3. Patterns representing numbers two-nine (Uprichard-Wilson).

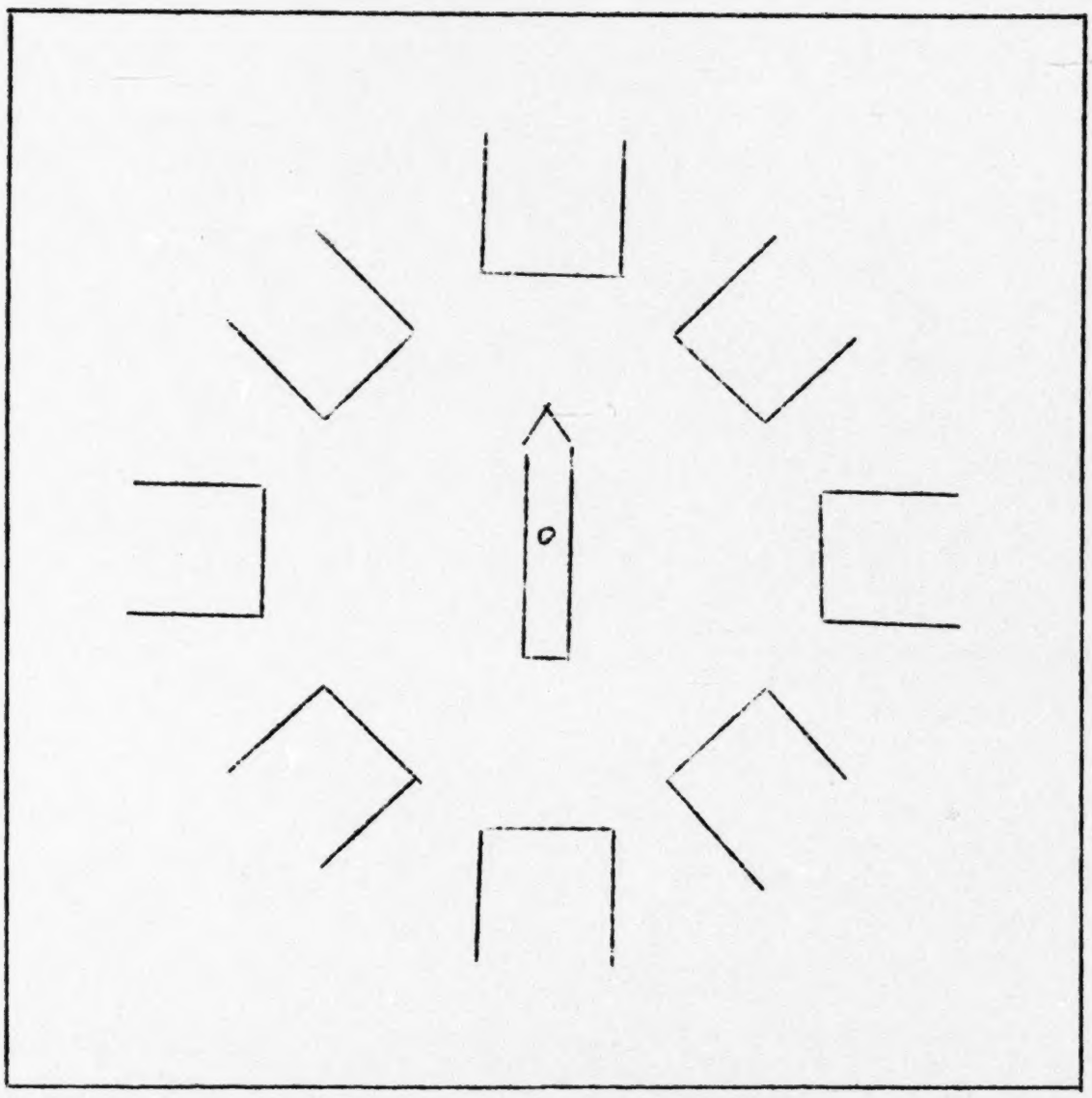


Figure 4. Diagram of spinner cloth used in instruction.

Order-class panel - collapsible cardboard panels each with three vertical columns. These may be placed side by side to create a single order class panel with nine vertical columns.

HOW GAMES ARE PLAYED

All of the "Find It" and "Make It" games follow the same basic procedures outlined in the Detailed Game Plan. The following are brief descriptions of typical games used in Stage I to develop the one-to-one correspondence relation.

Find It

Set boards of a specified pattern are placed in the slots of the spinner cloth. A group of three to six children sit around the spinner cloth. Each child has a set board of a specified pattern. (The patterns used - Standard, Bilinear, Scatter, or mixed - depend on the level of the concept being developed.) Each child places one block in each hole of his board. The teacher or a child spins the spinner.

The teacher picks up the set board indicated by the spinner and says; "This is a set of (four). One, two, three, four (pointing to each hole). Who has a set that matches (or is equivalent to) this set?" Any child who thinks his set-board is equivalent to the sample set board may respond. The teacher does not tell him if he is right or wrong, but leads him to check his own response using the appropriate self-confirmation process.

For the one-to-one correspondence relation, the confirming process is as follows: the child removes the blocks from his set board and places one block in each hole of the sample set board. The child's set board is equivalent to the sample if, after moving the blocks, all his blocks are used and all the holes in the sample are filled. (It is hoped that the child better sees the role of the transitive property by making use of three concrete sets - holes in sample board, holes in child's set board and blocks. In far too many lessons given to young children, the third set needed to mathematically compare

two sets is not seen by the learner and he is unaware of its existence, i.e. the use of the sounds we refer to as counting to compare two sets.)

Psychologically, the importance of the self-confirming process cannot be overemphasized. It helps the child toward independence, as he learns to become his own source of authority for judging success in mathematics.

An appropriate self-confirmation process using concrete materials is available to the child at all levels of development for the three concept areas developed in Unit I of F.U.N. For example, in Stage 1 the self-confirmation processes for greater than and less than are as follows:

Greater than: The child's set board is one (or more) greater than the sample if, after moving the blocks, all the holes in the sample are filled, and the child has one or more blocks left.

Less than: The child's set board is one (or more) less than the sample if, after moving the blocks, all his blocks are used but one or more holes in the sample is empty.

Make It

The Make It game is similar to the Find It game. However, there are three basic differences:

1. Instead of having his own set board, the child has several blocks, other small objects, and/or materials needed to make non-spatial sets.
2. When the spinner points to the sample set board, all the players try to make a set which is equivalent to the sample.
3. An appropriate self-confirmation process is used.

USING F.U.N. IN THE CLASSROOM

There is no one way to use F.U.N. There are as many organizational plans, as many supplemental activities, and as many extensions as the creativity and desires of individual teachers permits. The following are simple "starter suggestions," based on experiences during field testing of the program.

When should F.U.N. start, and for what groups?

The research upon which Unit 1 of F.U.N. is based, involved nursery and kindergarten children. The program has been designed primarily for children of functional ages 3 1/2 to 6. However, at just what age F.U.N. should be started, and what the pacing through the levels should be, will depend primarily on what experiences a particular group of children have had available to them.

For nursery school children, Stages 1 and 2 of Unit 1 could be the basis for a full year's work, followed by Stages 3 and 4 the following year. Kindergarten children who have not previously worked with the program may be able to complete all of Unit 1 during one year. In first grade, F.U.N. may be used as a readiness program or to supplement the regular mathematics textbook. F.U.N. is also suitable for remedial work, and with the educable mentally retarded.

How long for each session?

Children should play both the Find It and Make It games for a given level in the same session. Each session should last only 20-30 minutes, with 10-15 minutes devoted to each game. There can be no predetermined number of sessions per level of a concept. This, of course, depends entirely on each child's rate of learning.

How many sessions per week?

Field-test teachers typically held three sessions per week. Several teachers observed growth with only one session per week. These teachers, however, were very creative in supplementing the games with other related games and activities in art, music, etc. Several supplementary activities are suggested in the teacher's guide i.e. F.U.N. Rummy, F.U.N. Bingo, etc.

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